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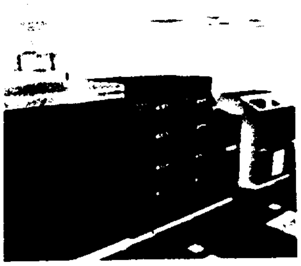

TECHNICAL REPORT ITL-89-1

WES COMMUNICATIONS PLAN FOR VOICE AND DATA

by

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The development of an advanced plan for office automation, the proposed implementation of an on-site supercomputer, and imminent plans for a corporate data base will overburden the existing communications network at the Waterways Experiment Station (WES). These events have accelerated the requirements for WES to upgrade its current communications network to handle the needs of the next 15 years.

Plans are being formulated to integrate the data requirements of the entire WES site by constructing a state-of-the-art high-speed digital network capable of handling any kind of traffic. The ultimate objective is to allow any user to transparently communicate with any other device on the network.

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PREFACE

The development of an advanced plan for office automation, the proposed implementation of an on-site supercomputer, and imminent plans for a corporate data base will all overburden the existing communications network at the Waterways Experiment Station (WES). These events have accelerated the requirements for WES to upgrade its current communications network to handle the needs of the next 15 years.

This report analyzes the present communication facilities at WES and provides a formula for the construction of a state-of-the-art network capable of handling any kind of traffic. The ultimate objective is to allow any user to transparently communicate with any other device on the network.

A major factor that indicated a need to upgrade the WES communication facilities was the apparent inability to expand the Dimension 2000 premise-based voice system to support additional asynchronous dial-up modem traffic. In June 1987, Dr. N. Radhakhrishnan of the WES Information Technology Laboratory (ITL) commissioned Dr. Michael B. McGrath, of the Colorado School of Mines, to study the current situation and recommend a solution.

The WES Communications Plan for Voice and Data is modeled after networks that have been installed in major universities throughout the United States. Dr. McGrath visited several of these universities during the summer of 1987 and his experiences are summarized in Appendix A.

Efforts involved in this report were monitored by ITL personnel including Messrs. Jerry Graham, Pat Spencer, Ed Woods, and Ed Fowler. The report was prepared under the supervision of Drs. Windell Ingram and N. Radhakhrishnan, ITL.

COL Dwayne G. Lee, EN, was Commander and Director of WES during the preparation of this report. Dr. Robert W. Whalin was Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres

WES COMMUNICATIONS PLAN FOR VOICE AND DATA

PART I: INTRODUCTION

Background

1. The present communications system at the US Army Engineer Waterways Experiment Station (WES) consists of a Dimension 2000 premise-based voice system (PBX) and very low-speed data communications by the laboratories using 1,200/2,400-baud asynchronous modems over analog phone lines, and 4,800-baud synchronous modems for computer-to-computer communications over leased lines. There is considerable traffic to the outside world using 1,200/2,400-baud modems for access to supercomputers. In addition, there is also considerable traffic from the divisions and districts into WES for access to administrative computing through multiplexers and modems. The present system is severely limited and there is considerable demand for better terminal access and high-speed communications.

2. The individual laboratories have 31 VAX computers and over 800 personal computers (PC's), and are beginning to install Local Area Networks (LAN's) for both the PC's and VAX's. A supercomputer project has been approved and is planned for installation in the 1990's. A very comprehensive project management system is presently under development and planned for use in the next few years. Office tasks are being handled on NBI systems and are in need of updating. All of the above projects require a comprehensive communications system to make effective use of advanced computer technologies.

Communications Technology

3. Communications technology has been developing slowly since the late 1960's but has accelerated in the last several years. The 1970's were characterized by low-speed terminal communications using data switches and eventually multiplexers to access mainframe computers. Long-haul communications needs resulted in the ARPANET network and eventually the Defense Data Network (DDN). The Ethernet network was developed in the late 1970's and has evolved into a mature set of products today. The growth of PC's in the 1980's has

driven the development even faster. It is estimated that over 50,000 PC-based LAN's have been installed since 1985.

4. While the Very Large Scale Integrated Circuits technology and the ubiquitous PC have contributed to the growth of data communications networks, the most positive impact on the orderly growth and development of this field relies on the development of standards. There are already several sets of standards in place today and most vendors have embraced the Open Systems Interconnect (OSI) model for future communications standards. This makes it possible to design a communications system that is vendor-independent and further allows machines of different vendors to communicate over a single system.

Goal

5. The goal of this plan is to develop a comprehensive communications system for WES for voice, data, and video. The plan provides a design that will satisfy the communications needs for the next 15 to 20 years and will be a firm foundation for growth, providing a flexible vehicle for future expansion.

Approach

6. The approach used in this planning process is based on several assumptions and ground rules that are described in detail in Part IV and on the computing activities planned for the next 5 years. The major activity driving data communications needs at WES is the planned installation of a supercomputer. The investment in this facility will be over $25 million. This size of investment justifies a comprehensive communications system that allows high-speed access for computing and file transfer both on and off the Station.

7. WES needs to be a leader and a showcase for computing and communications technology. The supercomputer project provides WES with the unique opportunity to develop this capability. The plan is based on the model of major research universities that have supercomputers and extensive communications in place or planned. These systems are discussed in detail in Appendix A.

8. The most important ground rule is that the communications requirements must be met in a multivendor environment. The evolving standards allow a variety of LAN protocols to communicate over the network. This will also provide the flexibility to grow with technology such as workstations and yet preserve the investment in present computing equipment.

Plan

9. The plan is based on ground rules and assumptions about the future of WES activities and the growth of computing and communications technology. Evolving communications technology is best illustrated in Figure 1. Most

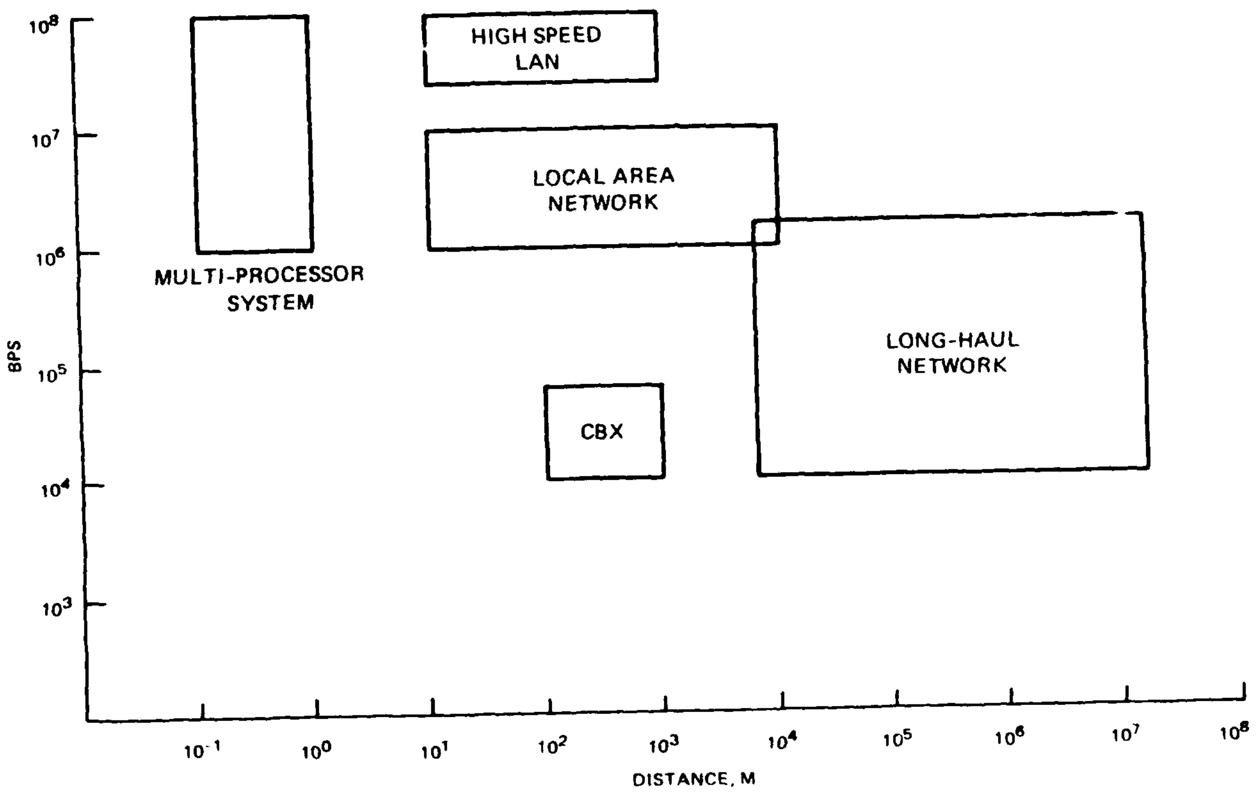

Figure 1. Comparison of communication ranges

communication today is through the Central Branch Exchange (CBX) using 1,200-baud modems, although the CBX will support up to 9,600 baud. Long-haul networks generally consist of 56-Kbps or 1.544-Mbps rates between CBX's.

LAN's extend data rates to 10 Mbps, and special high-speed LAN's can interconnect local networks at over 100 Mbps. A multiprocessor system is usually a multiuser, multitasking computer which supports many users by direct-connect terminals.

10. The WES communications plan addresses three major areas: voice (CBX), LAN's, and high-speed LAN's. It is based on a future design that envisions a facility where everyone is attached to an LAN and all computers can communicate through a high-speed LAN. The plan provides for a phased approach to the final design by providing for low-speed terminal access through switching networks.

11. The plan provides recommendations for meeting voice, data, and video requirements. It includes an implementation plan and schedule and an estimate of costs. It also discusses management issues and recommends staffing levels to support implementation of the plan.

PART II: PRESENT SYSTEM OF VOICE, DATA, AND COMPUTING

Configuration of Voice and Data Systems

12. The present system of voice and data consists of a Dimension 2000 PBX located in Building 1073 and an Infotron data switch located in Building 1000. The D2000 PBX provides approximately 2,360 voice lines, of which approximately 500 are used primarily for 1,200-baud modem traffic. The Infotron data switch operates independently of the PBX and allows switching of some 500 asynchronous RS232 ports among terminals and host computers. The Infotron is a port contention device. Access to the Infotron allows the user to connect to the services listed in Table 1. Figure 2 shows the present configuration of the D2000 and Infotron voice and data systems.

Hardware Description

13. WES currently has a Dimension 2000 PBX with Feature Package 7 installed prior to 1981 under the two-tier payment plan offered before divestiture and is currently paying only the tier B portion of the contract. The system is configured with four network modules, duplicate common control, and a magnetic tape Station Master Detail Recorder unit. System power is provided by an uninterruptible power supply configuration with 24 wet cell batteries and Lorain inverters. A physical inventory was performed to determine the current capacity of the system and the growth potential of existing equipment.

Table 1

Services Available via Infotron

Destination	Speed Baud	Host
WES	ABR	DPS-8 at WES
TEC	9,600	Thomas Eng Protocol Conv
TED	1,200	Thomas Eng Protocol Conv
IBM	ABR*	IBM 4331 (3270 emulation) at WES
HAR	ABR	Harris 500 at WES
CDC	ABR	CDC at Kansas City
CDD	2,400	CDC at Kansas City
HAX	ABR	Hydraulics VAX at WES
PRISM	1,200	DPS-8 at WES
OUTD	ABR	CTS Outdial Modem at WES

* ABR denotes auto-baud rate.

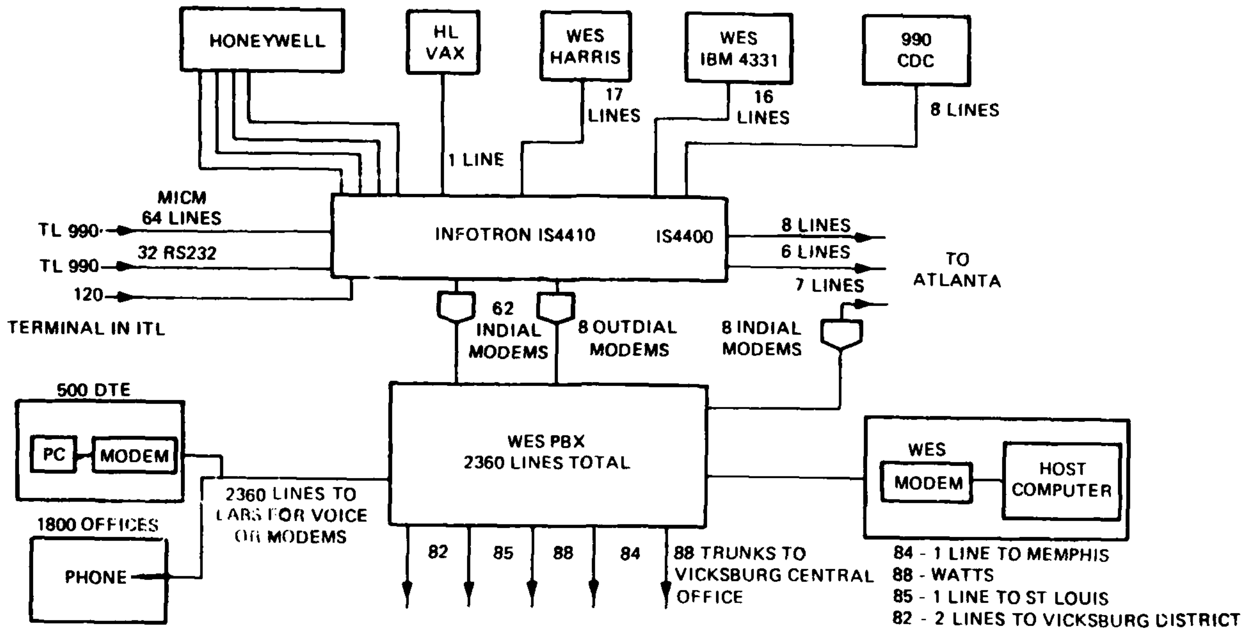

Figure 2. Present configuration of D2000 and Infotron voice and data systems

The current system was found to have physical excess capacity to allow for 21 percent growth in central office type trunks, 40 percent in four-wire type trunks, and only 7 percent Station growth (approximately 161 stations). The results of the physical inventory also indicated that the current memory configuration limits the total number of station terminations. The system at WES can be expanded to an upper limit of 4,096 lines with additional hardware. The following are the current equipment capacities of the system.

a. 2,360 main station lines.

b. 88 central office type trunks (DOD and WATS).

c. 28 outdial WATS.

d. 6 tie lines.

e. 2 attendate consoles with DSS (1 console repeater 5000).

f. Attendant conference circuits.

14. The common equipment is located in Building 1073 and acts as a central office for the approximately 107 buildings located throughout the 800-acre facility. All Station lines are considered "off-premises" stations to the main switch. Construction of new buildings in the northeast corner of the installation will increase the Station requirements of the system. Each laboratory has its own community of interest and should be autonomous in its

operations from other laboratories but should be able to communicate with others when necessary.

15. Each laboratory at WES has a variety of data equipment in support of its own operations. There are a variety of computers and special-purpose LAN's located throughout the installation. The current data communications network providing connectivity between this equipment and other systems at WES and systems off premises is composed of low-speed, analog, dial and private line modems transmitting over copper-based facilities. Voice system station extensions or four-wire circuits operate through the Infotron 4400 data switch which functions as the main communications center and is located in Building 1000. It is anticipated that requirements for enhanced networking and more flexible user interfaces on the installation will increase in the future.

16. The main data system, located in the Headquarters Building (Building 1000), interfaces with a Honeywell computer system with a Datanet 8 front-end processor. Communication with this and other computer systems at WES is accomplished through the Infotron IS4400 data switch which interfaces with the WES multiplexer network consisting of Infotron TL780/990 multiplexers transmitting to other engineer districts in the Lower Mississippi Valley Division (LMVD). This system also serves as a data center for the US Army Engineer District, Vicksburg (LMK) and the Mississippi River Commission.

17. The WES data communications network currently operates at 9,600 bps using AT&T Dataphone II diagnostic modems with Level 2 diagnostics. The IS4400 also provides connection to a dial-up modem pool consisting of multiple 1,200-bps modems with capability of 4,800 baud over synchronous modems to the districts. These modems, attached to the Infotron 4400, are also part of the main communications center. With the anticipated increase in data traffic at WES, there has been interest in increasing the speed of the network to 1.544 Mbps and the utilization of microwave transmission between WES and the other LMVD districts.

18. The installation's cable plant is an all-copper network connecting all buildings to the main PBX in Building 1073. The majority of this cable plant was developed to support voice communications on the installation. Many of these cable runs are being fully utilized. Because of this and the age of the existing cable, requirements for additional cable facilities to support both voice and data transmission to several buildings include the expense of contracting for new copper cable from Building 1073. New cable is also

required for the new buildings being constructed.

19. All buildings on the installation are wired to provide a minimum of two copper pairs for each voice extension. Several Key-Systems are spread out over the complex requiring 25-pair wire runs from the individual building equipment closets to the instrument locations. LAN's in the laboratories utilize copper and coaxial cable to provide internal data connectivity of terminals and computers in the laboratory area. The wiring scheme was developed primarily for the voice system and must be continually modified to allow for the increasing amount of data transmission requirements and the addition of new Station extensions.

20. The design of the present data communications network configuration does not allow for quick and easy additions and rearrangements. With each new data transport requirement, the system must be analyzed to determine if new data communications equipment will be needed. This causes unnecessary delays due to the time frames involved in obtaining the equipment and the coordination required in providing facilities.

21. An alternative solution is to expand our present system using data-over-voice (DOV) multiplexers. In order to gain more extension numbers, the D2000 PBX must be upgraded to memory configuration "E" which allows for system expansion beyond the 2,360 extension circuits of the current configuration. The use of the DOV's will solve this limitation by allowing simultaneous voice and data traffic using only one extension circuit.

22. WES is also in the process of upgrading the 212A modems to 2224 type. These modems are located in the main communications center in Building 1000 and interconnect to the Infotron IS4400 data switch. Each of these modems, which total approximately 70, also requires a main PBX extension circuit. This is the Station's primary means of local area connectivity and has further taxed the available resources of the D2000 voice switch.

Uses

23. Networking of computers within WES generally consists of RS232 port contention between the IBM 4331, Honeywell, and Harris 500 computers in the Information Technology Laboratory (ITL) (Building 1000) via the Infotron 4400 data switch, connectivity to mainframes via 1,200/2,400-baud modems, connectivity of local VAX clusters by Digital Equipment Corporation Network (DECNET), and isolated PC networks. The need for high-speed (56K baud or higher) networking is obviously essential at WES. While the Infotron data

switch provides a low-speed network in ITL (Building 1000), it does not supply user statistics on connect time and bytes of data transmitted and received during a session.

24. The Dimension 2000 PBX is denoted as "limited usage" technology by AT&T, with support consisting of manufacturing standby to supply parts as needed to maintain existing systems. WES has experienced problems in the past with expanding the D2000 PBX to obtain the number of voice lines required to support WES activities. The use of DOV's must be considered as temporary only, since the DOV's are used only in conjunction with the D2000 PBX and can provide low-speed data communications only as long as WES retains the D2000 PBX.

Map of Station

25. WES encompasses approximately 800 acres* with over 100 buildings on site. In general, all locations at WES are serviced by the D2000 telephone system; access to the data switch in Building 1000 from inside Building 1000 is by direct connection, and from outside Building 1000 is by in-dial modem. Leased lines tie the Infotron 4400 data switch to other Corps locations (see Figure 2). A map of the Station is shown in Figure 3.

Description of Computing Environment

NBI

26. The NBI is a dedicated word processor that can be networked only with other NBI machines. A plug-in option card enables an IBM PC/XT to run NBI software. The use of the option card in an IBM machine, with Carbon Copy or Remote Access software, allows NBI functions to be networked on an Ethernet, Arcnet, or any other LAN architecture. The present 3-year contract for NBI at WES has ended; WES is presently evaluating an option to continue with the NBI dedicated word processors for the next 1 or 2 years.

DDN

27. In April 1982, as a result of an intensive internal study of alternative systems, the Department of Defense (DOD) directed that the DDN, based upon ARPANET technology, be implemented as the DOD common-user

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* A table of factors for converting US customary units of measurement to metric (SI) is presented on page 4.

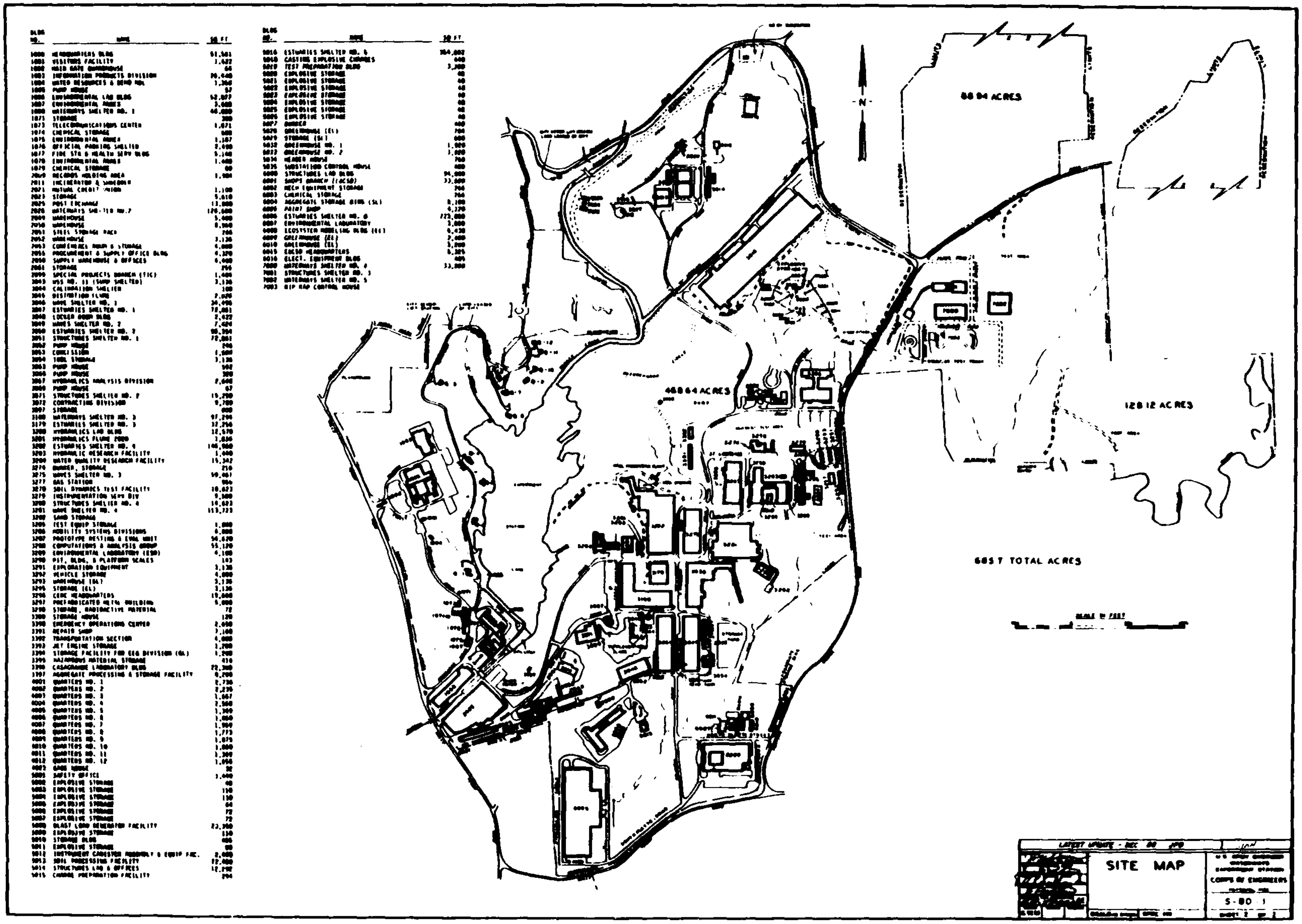

Figure 3. Map of WES facilities

data-communications network. Office of the Secretary of Defense policy issued March 10, 1983 states:

> All DOD ADP systems and data networks requiring data communications services will be provided long-haul and area communications, interconnectivity, and the capability for interoperability by the DDN. Existing systems, systems being expanded and upgraded, and new ADP systems or data networks will become DDN subscribers. All such systems must be registered in the DDN User Requirements Data Base (URDB). Once registered in the URDB, requests by a Service/Agency for an exception to this policy shall be made to DUSD (C31). Requests for exceptions for joint interest systems shall be routed to DUSD (C31) through the JCS.

28. WES has active requests for DDN on the Honeywell computer and on the VAX. DDN will first be implemented with X.25 basic, until the X.25 standard becomes available.

Honeywell

29. Communications on the Honeywell Computer System include two hundred asynchronous ports, thirty synchronous ports, one 9600 High Level Digital Link Control (HDLC) line direct-connected to the DPS-6, one 9600 HDLC to be connected to the EASA Honeywell by a 19.2K synchronous modem on a leased line, one 9600 HDLC line to be connected to SWD by a 19.2K synchronous modem on a leased line, and two wideband HDLC 56K connections not used on the Honeywell.

30. Honeywell DPS-8 configuration, as of October 1987, is as follows:

a. Dual Processor's 8/70 control processor unit (CPU).

b. Two megawords or eight megabytes core memory.

c. Twelve Mass Storage Unit (MSU) 500 disk units.

d. Four MSU 451 disk units.

e. Four MSU 501 disk units.

f. Fourteen 9-track (1600/6250) tape drives.

g. One 9-track (800/1600) tape drive.

h. One 7-track (800/556) tape drive.

i. Two system consoles.

j. One card reader and one card punch.

k. Two communications processors.

l. Thirty synchronous ports.

m. Two hundred asynchronous tss ports.

n. Total disk capacity = 9 850 776 llinks.

o. Current disk used = 6 356 616 llinks.

p. Available disk = 3 494 148 llinks.

31. Averaging 70 users per day with a peak above 90 users (Sep-Oct) and a core utilization of 98 percent, another processor and additional memory (8 mb) are on order.

VAX

32. VAX computers comprise a large portion of the minicomputer system at WES. Most of these operate as small clusters of VAX systems linked by DECNET over Ethernet cabling. Appendix B contains a detailed description of location and usage for these computers.

PC's

33. WES owns over 800 IBM PC's and compatibles. These PC's generally exist as stand-alone machines with some networking in isolated portions of WES. Communications to the PC's are presently accomplished with 1,200-/2,400-baud modems.

Other Systems and Uses

US Army Corps of Engineers (USACE) radio

34. The USACE radio program is a network of high frequency/single-side band base and transportable radios with over 10,000 frequency assignments that can communicate over a range of 1,200 miles with 90 percent reliability. The radios are primarily for emergency use and are mentioned here only briefly because they are not linked to the wide area network.

35. The high-frequency radio program is funded at $12 million, with the Corps' portion totaling $1.2 million. By the end of 1988, all Corps locations are scheduled to have either a base station or a transportable (called the HF reconstitution radio). These radios operate over 2 to 500 MHz, and at lower frequencies can communicate over greater distances using Ionospheric bounce. The radio can generate 1,000 watts and includes exciter, radio teletype (RTTY) and message terminal, high-frequency modem, and remote control equipment. An installation team will arrive with the radio, and site preparation must be provided in advance. The radio is primarily for emergency voice in the event of a failure of the phone system and has no data capability other than RTTY. The program is scheduled for completion in February 1989.

Local exchange

36. A fiber optic from Vicksburg to Jackson, MS, was activated as of February 1987, making possible digital communication by 56K line or by T1 carrier. In May the crossbar switch at the local central office in Vicksburg was replaced by a 5ESS switching station.

37. Replacement of the D2000 PBX with Essx may involve construction of a second local exchange by South Central Bell (SCB) in a location convenient to service WES.

District microwave communications

38. The Vicksburg District is connected to other districts by a microwave chain supporting 600 voice channels. This system was installed over a 5-year period at a cost of $8.5 million. A 600-channel handie-talkie allows access into the system from field location. One channel on the handie-talkie is designated for telephone autopatch. With this feature, a user can dial into any local telephone system anywhere along the microwave chain from the Gulf of Mexico to Little Rock, AR (with no long distance charges). The handie-talkies also can communicate directly with each other over limited distances.

39. Microwave repeater stations are separated by approximately 20 miles. Since the system accommodates voice channel bandwidth, data transmission would be limited to rates typical of voice band channels (1,200 and 2,400 baud) although the microwave system is not presently used for data.

PART III: FUTURE SYSTEMS AND GOALS OF THE COMMUNICATION PLAN

40. This part contains a projection of the future of computing and communications at WES. Because this document is a communications plan, it emphasizes the design of a wide-area network for voice, low-speed data (up to 19.2K baud), and high-speed data for the support of computers and facilities located at WES.

Corporate Data Base (CDB)

41. The CDB will provide information to network users on projects, status, and activities. Presently the software for the CDB is being developed on an IBM 9370 computer, however, the CDB may be run on the Corps of Engineers Automation Plan (CEAP) machine when it arrives. All laboratories within WES will have equal access to the centralized CDB, with the capability of file transfer and data entry on the IBM 9370.

42. Networking to the IBM 9370 will be via a local area network attachment and will include an IBM 3174 asynchronous interface unit for in-dial and out-dial modems.

43. A system network architect (SNA) gateway to the IBM 9370 would be the recommended way to interconnect it to the WES VAX computers.

Office Automation (OA)

44. Office automation (OA) generally has meant NBI word processors, but in the future will be expanded to include electronic mail (E-mail), file transfer, library access, and manuscript and document preparation. Each laboratory will potentially have a 4-Mbps office automation ring, or an Ethernet, which will be the networking attachment point to the rest of WES.

CEAP

45. The CEAP computer remains an unknown at this time. Location of the new CEAP computer is anticipated to be in Building 8000 (the new ITL building under construction). Transition of software from the Honeywell computer to the new CEAP computer will necessitate the use of both the Honeywell and the

CEAP computers for a limited time. Other Corps locations will experience difficulties during the transition phase as their Honeywell computers are replaced by the new CEAP machine. WES desires to allow other Corps divisions usage on the WES Honeywell for the transition period.

46. A 56K-baud digital line will be installed as part of the CEAP project and will connect EASA, WES, and the US Army Engineer Division, Southwest.

47. Networking to the new CEAP computer will be through RS232 asynchronous ports, a DDN connection, and a vendor-provided network that operates over the 56K-baud digital line. Communications to the CEAP computer will not be through DDN for at least the first five years of use.

Army Civilian Personnel System (ACPERS)

48. ACPERS is a worldwide Department of the Army project to upgrade and standardize data processing support for Army civilian personnel administration. It is designed to perform four primary functions for the Army: (a) support mobilization, (b) replace existing systems, (c) meet expanded peacetime requirements, and (d) interface with other automated systems. ACPERS will support the Army Civilian Personnel Offices in the recruitment, training, distribution, retention, and separation of personnel.*

49. ACPERS equipment will not be installed at WES and there are no present plans for WES to use the ACPERS system.

Army Supercomputer

50. Because WES is such a large user of supercomputer time, spending about $3.8 million annually, the delivery of a supercomputer is scheduled for the new ITL building (Building 8000) in 1989-1990. Networking to the supercomputer will probably be via a VAX 8800 front-end, running both DECNET and Transport Control Program/Internet Protocol (TCP/IP) under a Wollengong software package. A 50-Mbps, or higher, fiber-optic link will fully support supercomputer access. In addition, the system will be able to access the Army

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* "Communications Plan; Army Civilian Personnel System (ACPERS)," prepared by the US Army Information Systems, Engineering, and Integration Center at Fort Huachuca, Arizona, under contract DAEA-18-84-D-0058.

Supercomputer Network and DDN and will provide async and Ethernet port connections with Digital Equipment Corporation (DEC) VAX/VMS computer systems and UNIX-based machines. The supercomputer is anticipated to have ports for remote job entry.

51. Complete documentation of the interface requirements for the supercomputer is given in the document entitled "Army Supercomputer Site Management Plan for Supercomputer Node to be Located at USAE Waterways Experiment Station."

PC Terminal Emulation Software

52. Vistacom is a communications software package for the IBM PC/XT/AT and is proposed to be the standard communication package for the Corps. Vistacom supports asynchronous communications, has 12 types of terminal emulation, and can handle both secure and nonsecure file transfers. File transfer capabilities include Kermit, XMODEM, Vista, and CONNECT, the last two being Control Data Corporation proprietary standards. A site license is in effect at WES for Vistacom.

53. Vistahost performs Huffman code compression and allows bidirectional file transfers.

54. Within a year LAN support will be incorporated into the Vista family for Ethernet local area networks. Future enhancements include X.25 support and Honeywell visual information projection emulation.

Secure Telephones

55. Within 2 years, the STU-III (secure telphone unit) telephone is scheduled to replace many of the handsets used by the Corps. These are analog handsets that can handle unclassified information but are sensitive to top secret information. Implementation will begin in the fourth quarter of 1988. The handsets require 110VAC and use a standard RJ11 phone jack.

56. The STU-III is manufactured by three different vendors and is available in different versions. There are single-button and six-button handsets available. These handsets can be adapted for intergrated systems digital network (ISDN) when it becomes prevalent.

57. The STU-III price ranges from $2,200 to $3,700 per set, but the

Army bears the entire cost. Over 500,000 STU-III's will be purchased for all departments of the Army at a cost of over a billion dollars. Since use of the STU-III telephones is not a mandatory replacement for all phones at WES, possibilities still exist in this communication plan to use Northern Telecom handsets, continue the present lease on AT&T handsets, or pursue other options.

Video and TV

58. Since present fiber-optic technology can accommodate only a few video channels per fiber, a coax cable may be installed along with the fiber. The capacity of the coax is 62 simultaneous video channels over a wide bandwidth. No community aided TV (CATV) equipment is planned for the installation other than the initial coax, but trunk stations, line extenders, head-end equipment, and set-top converters can be added later to activate the video facility.

Electronic Mail

59. Electronic mail (E-mail) for the Corps is presently implemented on the ONTYME System.

60. The diversity of LAN's inside WES will make electronic mail difficult. The X.400 is the CCITT standard for electronic mail and is supported by all major host vendors. The X.400 defines protocols for the transmission of electronic mail among different office systems. Users would be able to take advantage of the proprietary features of each network and have the ability to communicate with everyone else on the Station regardless of which network they reside in. DEC and Hewlett-Packard (HP) have promised to adhere to the finalized specifications, even though the X.400 standard is still being formulated. IBM has promised a gateway between their SNA environment and X.400. There are very few X.400 products available today and no conformance testing available to guarantee that one vendor's implementation will be compatible with another.

61. One problem with the current crop of E-mail bridges is the lack of a multisystem electronic mail global directory. Users should be able to identify any other E-mail recipient on any system. The X.400 standard will eventually make this feature standard.

PART IV: ASSUMPTIONS AND GROUND RULES IN DESIGNING THE NEW SYSTEM

62. Design of the voice, data, and video systems for WES is based on a number of assumptions and ground rules. The assumptions concern technology and computing activities either under way or being planned, and dictate the ultimate design. The ground rules concern such things as the standards the industry is presently adopting and vendor independence that affects interconnectivity. The following discusses each area in detail and attempts to indicate how the assumptions affect the ultimate design.

63. Many of the assumptions are based on industry practice; however, some are based on the particular culture and emphasis on computing activities at WES. Probably the single most important assumption affecting the design is that WES plans to be a leader in computing and communications technology and a showplace for the entire Corps. The decision to be the location for a supercomputer center demands a sufficient communications system. To this end, the design provides a comprehensive communications system that will provide the basis for this to happen.

Driving Forces in the Design

64. The major activity driving the design is the supercomputing project. A $25 million investment for computing equipment requires a communication system that provides high-quality access to the user community at WES as well as access to off-station users.

65. A second major activity that requires station-wide access to a central computing system is the CDB. The individual laboratories will need access to the CDB, which will be housed in a central location for data entry and data retrieval. This could mean a potential for very large use of the central system.

66. The laboratories have a considerable investment in VAX computers for data acquisition and general computing. Several laboratories already have their own VAX's connected by Ethernet Systems and the remaining laboratories are planning to install such nets. This plan makes the assumption that eventually all of the VAX computers will be interconnected by an LAN with many users connected to the LAN. This will probably happen in a relatively short

time given the high interest level and the maturing of the Ethernet System by DEC.

67. There is growing interest in a PC-based LAN among the PC users in all of the laboratories. That industry is possibly one of the fastest growing areas in the entire field of computing and offers real advantages of sharing and access to resources on other LAN's. This plan makes the assumption that a vast majority of PC users will be on a PC-based LAN within a few years. If that is true, then the access to departmental or central computers will be through the user LAN that is interconnected to other LAN's. Eventually the copper wire access will be used only for a few cases including sites too remote to connect to an LAN or for the person who is an occasional user. This assumption has major implications on the choice of an intermediate low-speed data system to meet the immediate needs for access to the central computers and to departmental computers.

Culture

68. The laboratories are independent and make their own decisions about computing and communications. However, they look to ITL for leadership in setting directions for central services such as communications and supercomputing. The laboratories will establish Ethernet LAN's for their VAX computers but look to ITL for the means to connect to the supercomputer and for management of the Station communications system. A communications system is by its nature a distributed system that needs central management such as coordination of access, maintenance, and repair.

Technology

69. Communication in the past has been primarily on copper wire using a central computer for the switching functions, with intelligent multiplexing devices at remote locations to extend the reach of the wire and to eliminate multiple connections. This is the same technology that the phone system is based on. However this technology is past its useful life for any application that has a significant amount of data traffic. The central switch has an inherent limitation in the amount of traffic that it can handle and the industry has moved to the LAN as the solution to communications of the future. The

plan makes use of copper-wire-based terminal access for the short term but plans for eventual access through LAN technology. Therefore, the short-term solution has to be one that allows the flexibility to add and drop service as the need dictates.

70. One of the major causes of the growth of the LAN technology is the set of standards that are being developed and adopted by the major vendors. Because of the standards, the industry is able to build the technology using chip technology, and the cost and capability of the LAN's are improving at a very fast rate. This plan is based on standards and requires vendor independence. The development must allow a variety of vendor equipment to be attached to the facility-wide LAN and this is possible only through strict adherence to communications standards. The most notable one is the OSI model that fortunately most of the major vendors have embraced as the eventual solution worldwide.

The 802.5 token passing ring technology

71. While the majority of LAN's are Ethernet-based using the 802.3 standard and baseband technology, the 802.5 token passing ring technology is gaining popularity and promises to offer the high data rates needed for a backbone system. The Fiber Distributed Data Interface (FDDI) standard that is under development uses the token ring and 100-Mb speed. The WES plan is based on using the FDDI-II standard when it is available. The intermediate design is based on Ethernet, and 4- and 10-Mb ring technology to provide access to the supercomputer and to the CDB.

Fiber technology

72. Fiber technology is developing at a very fast rate for high-speed data transmission. It is being used extensively by the long distance phone companies. It is especially useful for token ring LAN's since this communication technique uses point-to-point connectivity whereas Ethernet uses a bus to broadcast the signal. This plan envisions a fiber cable running a token ring, or Ethernet, for high speed as the backbone LAN that all departmental LAN's will connect to. Although the Ethernet LAN's use coaxial cable for the transmission media, Ethernet on unshielded twisted pair, which is the common telephone cable found in buildings, is beginning to be available.

Video technology

73. Video technology is a well-established technology using CATV cable technology for analog transmission. The only interest at this time is for

video conferencing. The plan suggests the possible installation of a video cable, along with the cables for the backbone communications, for future use. This will allow future use without the expense of installing a cable.

Voice technology

74. Voice technology is presently a combination of analog and digital technology. There are systems on the market that combine voice and low-speed data in a single digital system, but this technology is not yet widely used and would be a demanding project to plan for and procure for WES short-term needs. Digital phone systems will almost certainly be the systems of choice of the future but that technology needs time to mature. Based on the short-term need for improved low-speed data access and the flexibility to replace the data system in the future, this plan does not consider the combined voice and data systems to be viable options.

Workstation technology

75. The final technology that will have a considerable impact on the design of the communications system is the emerging workstation technology. Workstations by definition have communications internal to the system. A workstation is a computer and communications system integrated into a single box. It also has a multitasking operating system and high-quality graphics capability. The cost of the monochrome workstation has dropped to the \$5,000 range for a diskless model and this will place a major demand on high-speed communications for file transfer and graphics applications. While the 1980's were the years of the text engine, the 1990's promise to be the years of the graphics engines, and workstation technology is the basis for that to happen. This plan assumes that the scientific and engineering community at WES will adopt this technology while the administrative users will move to a multitasking PC such as the recently announced IBM PC/2 systems.

Management Issues

76. The technology of low-speed data communications using a central switch and copper wire and modems is only remotely related to the new communications available on LAN's today. It is a mistake to think that WES can add a comprehensive communications system without developing a staff to manage it. Modern communication is really combined computing and communications systems that require a knowledge of both computing and data communications

technology. LAN's have distributed intelligence to the individual CPU's on the network and require a whole new technology to deal with the management and care of the network. LAN's will also require the laboratories to develop educated and trained staffs to administer and manage their own LAN's and the connections to the network.

77. This plan recommends that ITL take the leadership in developing and educating a staff who will in turn educate and train laboratory personnel to cooperate in building a modern network. A functioning network will not happen by trying to apply the experiences of the past to the new technology.

Model Assumptions

78. Based on the assumption that WES desires to establish a state-of the-art facility for computing and communications, this plan uses major universities with supercomputers as models for the future. Appendix A contains information on site visits to some of these universities. In all cases the universities have installed or are installing a network consisting of a fiber-optic backbone supporting a high-speed token ring that will evolve to the 100-Mb level of the FDDI standard. This backbone network supports a large number of LAN's and provides a quality communications service to the user community. This plan used these institutions as models for the WES design.

79. The plan also uses the approach that the proper design is to plan the environment for some time into the future and to base the intermediate solutions to reach that design. The future design is a fiber backbone using gateway technology to interconnect a wide variety of LAN's, both PC and mainframe, into a comprehensive network. To reach this goal requires some installing of partial solutions for short-term needs that will provide maximum flexibility for the future.

PART V: SYSTEM DESIGN

Introduction

80. In designing a comprehensive voice and data system for WES, the state of the current technologies of voice and data, the unique features of the WES environment, and the major projects planned and underway at WES were taken into consideration. The design plan for the next 3 to 5 years is based on three separate systems as shown below.

   a. An analog voice system to fulfill near-term needs.

   b. A low-speed (19.2-Kbaud) data switch to handle the terminal traffic to the central computers and department machines.

   c. A high-speed backbone system to handle the high data rates.

81. The design plan considers that the state of the art in digital voice systems and high-speed local area networks is evolving rapidly and standards are being developed but are not yet in place. The design calls for a phased approach to the three separate systems that is described in detail in the following section with the alternatives that are available to implement the design.

Justification for the Design Approach

82. An alternative approach would have been to rely on emerging combined digital voice/data systems such as Rolm and Errickson. However, these systems are not yet mature and are still more costly than the separate analog and digital switch technology, which is extremely mature and reliable. WES would not benefit from the new technology at this time but should review the state of the art in a few years after the data communications system is installed and operational and time is available to devote to a major new technology. The future will be based on the ISDN standard which is not presently fully defined and will probably not become a reality until the 1990's.

83. There are several approaches to using an analog voice system and these are discussed in other sections. Once a separate voice system is justified, the present major approach to providing digital communications for terminal traffic is the digital switch. The plan suggests using proven and

reliable digital switch technology for the present. The major assumption is that the local area networks, both PC-based and mainframe-based, will eventually provide the mechanism for terminal and workstation access to all resources and will thus replace the digital switch. Therefore, a flexible approach is currently needed to meet the immediate needs for access up to 19.2 Kbaud.

84. Finally, the high data rates that are predicted for the future can only be met by a very high-speed backbone LAN based on fiber-cptic cables to provide station-wide access to resources. This technology is evolving rapidly and being installed at the major research institutions in the country. The specific design depends on the unique circumstances at each institution, but there is no alternative at this time to a fiber-optic backbone system. The actual implementations are evolving to the use of gateways as the standards are developed. The WES plan calls for a phased approach using proven technology in the early stages and delaying decisions until the technology is sufficiently developed and WES' needs are pressing enough to make the next step. The actual use of the backbone depends on the installation and acceptance of departmental LAN's (both PC and mainframe) by the laboratories at WES.

Voice System

Requirements

85. The voice system should be functionally compatible with the present system and have the following features.

- *a*. Must have an analog interface for compatibility with existing handsets and with the STU-III phones.
- *b*. Must be cost advantageous with the present Dimension 2000 PBX and the associated SCB charges.
- *c*. Must be able to duplicate all existing features and access codes (for example, remote pickup, call forwarding, etc.)
- *d*. Must provide adequate trunk lines into Vicksburg, MS. The present number of trunks is 88 and is adequate during peak business hours.
- *e*. Must allow for transition to the new system without any interruption in service.
- *f*. Must allow key sets to operate in the same fashion as they do with the Dimension 2000 system.
- *g*. Must be able to be installed without wiring changes to the existing buildings.

h. Must allow WES to make changes directly for restrictions, number exchanges, and groupings.

i. Vendor must be able to provide 3-day turnaround time for response to WES problems and changes.

j. Vendor must provide on-site training on any new system.

k. Vendor must allow provisions for WES to increase, decrease, or terminate service, as desired by WES.

l. Vendor must be responsible for maintenance of the voice system.

Alternate implementations

86. WES is considering three possible alternates to satisfy the voice needs. They include:

a. Upgrade the Dimension 2000 PBX.

b. Lease or purchase a new PBX system.

c. Lease Centrex voice services from SCB.

87. Each of the three separate options will provide adequate voice services to WES but each has advantages and disadvantages. This plan provides the approach to be used but leaves the recommendations for the final selection to a comprehensive study that compares the three approaches based on costs, service, and needs. Each approach should be evaluated against the needs, based on a weighted criterion. The following will discuss the three options in general terms and indicate the scope of the evaluation study required to make a final recommendation.

Options for voice system

88. The Dimension 2000 PBX is a viable option provided that the data traffic can be moved to a separate service. AT&T can provide a guaranteed lease for 3 years at a fixed cost. The future beyond 3 years is uncertain, but it is certain that AT&T would prefer all customers to upgrade to a new PBX and will eventually drop service to the Dimension 2000 in an estimated 3 to 5 years.

89. AT&T has not yet offered a second choice of purchasing the remaining contract on the Dimension 2000. If purchase of the 02000 were feasible, WES could then contract for maintenance service separately. This option has considerable cost advantages but has to be weighted against the loss in service and the future of AT&T commitment to the product. The major point to be remembered is that the options must be compared on a life cycle basis and there are considerations other than cost that affect the decision (such as

service, commitment, availability for future expansion, and flexibility). The evaluation should also be done on the basis of the evolving ISDN standard, looking at the time frame and options that will become available. An unknown future would favor the conservative approach in decision making. New technologies always promise the best of all worlds, but deliver the same problems as the old.

90. The second option is to replace the present PBX with a new PBX. This option would cost more than retaining the existing voice system and would offer very little improvement. It would require considerable time and effort to justify, purchase, and install a new PBX that could become obsolete soon after it arrived. Numerous companies sell PBX systems and could provide WES with a competitive price. However, the Dimension 2000 lease is based on a very favorable arrangement that would be hard to compete against. Based on information collected and evaluated during the planning phase, this (second) option does not appear to be viable, from either a cost or capability standpoint.

91. The third option is a leased voice service from the local Bell Operating company, SCB. In Mississippi, this service is called Essx (Centrex) and consists of the voice switch located in a central office (as opposed to a premise-based system). It is the same voice service provided by SCB to the residential areas of Vicksburg, MS, and has some interesting capabilities that should be evaluated.

92. Many of the capabilities identified as needs include more than cost and are thus hard to quantify for comparison purposes. A possible approach would be to create a list of features and capabilities and assign weighted values to each category and score each option based on the ability to meet the need.

93. A possible set of capabilities include the following.

a. Hardware costs.

b. Installation costs.

c. Rewiring costs.

d. Training costs.

e. Staff costs.

f. Flexibility to modify service and features.

g. Control of the system.

h. Management software.

i. Reporting capabilities.

j. Reliability.

k. Upgrade capability.

l. Interconnection to LMVD and LMK.

m. Response of service.

The needs should be thoroughly analyzed to create the most complete set of criteria for evaluation.

Low-Speed Data System

94. The present low-speed data system serves the central machines only as a port-contention device. There is immediate demand for a station-wide service for terminal access (primarily asynchronous) to both central and departmental machines. Long-term usage requires a much more comprehensive and robust access that includes terminals but also provides much more. The requirements are described in the next section.

Requirements

95. The low-speed data system should work in conjunction with the voice system and have the following characteristics.

a. Must be cost advantageous over the present low-speed data system.

b. Must be able to provide asynchronous data communications up to 19.2 Kbaud.

c. Must be able to operate in a data-over-voice fashion so that existing wiring can be used. (Existing wiring may be adequate for ISDN when ISDN becomes available.)

d. Vendor must allow provisions for WES to increase, decrease, or terminate service, as desired by WES.

e. Vendor must be responsible for maintenance of the voice system.

f. Must be able to allow user to simultaneously communicate via voice to one location, and have a data connection to a completely separate and independent location.

g. Vendor must provide WES with the following utilization statistics.

(1) The number and location of the originating station.

(2) The day and time that the connection was established.

(3) The length of the connection time.

(4) The number of bits transmitted and received per connection.

(5) The number and location of the destination station.

(6) The type of transmission (X.25, transparent synchronous, asynchronous, etc).

h. Vendor low-speed data network must allow user to maintain multiple simultaneous sessions in which the user can "hot key" between several applications.

i. The low-speed data system must be capable of the following:

(1) Switched bisync.

(2) Transparent sync.

(3) Ability to lock certain users from certain hosts.

(4) A 3270 support on a switched basis for bisync III.

(5) A 3270 support on a nail-up basis for SNA applications.

j. Emergency power in case of power failures.

Options for low-speed data

96. There are three alternative approaches to providing low-speed data access in the near future. They include the following.

a. Lease or purchase a new data switch to serve WES.

b. Expand the Infotron 4400 to serve other laboratories.

c. Lease central office service from SCB (called C.O.LAN).

All three options are viable and will meet the needs described above. Options a and b are similar, while option c is unique in that it is offered from a central office.

97. The data switch technology based on a central switch and remote concentrators is very well developed. However, switch technology is being replaced by LAN's. Data switches will continue to be used but will be in less demand as LAN technology expands. The three options offer data service for the next few years and should be evaluated and compared based on service, cost, and capabilities as recommended for the voice system. A major concern for a data switch is rewiring. The future is again uncertain and any extensive and costly rewiring should be carefully considered. The development of LAN's should determine the wiring design, not a service that will eventually be replaced.

98. DOV technology can be used in conjunction with the Infotron since the DOV's provide RS232 connectivity directly to the Infotron 4400. This eliminates the need for rewiring buildings, but additional Infotrons will still be required in other laboratories at WES.

High-Speed Data System

99. Future digital data communication will most certainly be a "network of networks." The WES network will extend from departmental-based PC networks to Station-wide networks connected to wide-area networks that are connected in turn to national and international networks. A surprising number of networks are in place at universities and research centers and are interconnected by national networks such as NSFNET and ARPANET. The major contributors to this technology are the integrated circuit and standards.

100. Ethernet is a mature and well-established technology. All workstations on the market today use the Ethernet technology in some form or other with a few using the evolving token ring technology. The token ring is growing rapidly due to the IBM announcement that the token ring LAN will be their future communications strategy. However, the networks of the future will use gateways to tie together multivendor systems. The gateway technology is in the early stages of development and is dependent on standards, the most important of which is the FDDI.

101. The FDDI standard is expected to be finalized in 1 to 2-1/2 years. There are already vendors manufacturing integrated circuits in anticipation of the standards, to reduce the cost of their gateway products. However, the technology is still evolving and any implementation must consider this. The WES plan proposes a phased approach to building a final comprehensive backbone network. The needs and the phased implementation are described below.

High-speed data communications requirements

102. The high-speed data system should have the following characteristics:

- a. Must be able to have a speed of 100 Mbps to support the FDDI-II standard.
- b. Must use fiber optic as the media for the main backbone. This cable is to be 62.5 micron, multimode, driven by a communications-quality light-emitting diode.
- c. Must allow full functioning of smaller networks such as SNA, DECNET, Ethernet, XNS, NBI machines, systems application architecture, token rings, etc. that hook onto the main backbone.
- d. Must allow peer-to-peer communication from any terminal or PC to any other computer on the network.

e. Must be able to accommodate vendor networks, based on fiber-optic cabling, in parallel to the main backbone.

f. The network should be able to support 1,000 users and over 2,000 nodes during peak periods.

g. The X.400 electronic mail standard should be used to allow electronic mail to be interbridged between LAN's.

h. System administration techniques must be able to be administered from a PC located anywhere on the network.

i. The backbone fiber-optic cable is to be bridged to the various laboratories by gateways.

j. The network must have access points for the following.

(1) 300/1,200/2,400 Hayes-compatible modems.

(2) 4,800-baud and 9,600-baud synchronous modems.

(3) RS232 interfaces.

(4) 3270-type interfaces.

(5) Access must be provided from the low-speed data network to the high-speed network.

(6) Gateways must provide interface points for 3COM, STARLAN, EXCELAN IBM TOKEN RING, ORCHID, PROTEON-4, PROTEON-10, SMC ARCNET, SYNOPTICS, ALLEN-BRADLEY, CODENOL, DAVID SYSTEMS, and GATEWAY PLUS networks.

(7) DDN.

(8) Hyperchannel interface to the WES supercomputer.

(9) ARPANET.

k. User statistics must be accessible by the system manager and should include the following.

(1) The location of the originating station.

(2) The day and time that the connection was established.

(3) The length of the connection time.

(4) The number of packets transmitted and received during the time the connection was established.

(5) The location of the destination station.

(6) The type of transmission (X.25, bisync, etc.)

(7) The routing for the call.

(8) Statistics should be on a session-by-session basis since the user can have multiple sessions.

l. Security features must be implemented as follows.

(1) Some of the fibers could be dedicated to secure networks.

(2) LAN's software may require logon identifications and passwords to designated host computers.

(3) System manager can use the network software to restrict certain users from any set of computers as required.

(4) Files in the host computers can be designated, using the network software, as read-only to certain users.

(5) Files in the host computers can be locked entirely from certain users, using the network software.

(6) Logon can be restricted to certain times for various users to designated host computers.

(7) Host computers will be capable of being placed in "secure" modes permanently, or for certain periods of time.

(8) Data may be encrypted using COMSEC compatible cryptonets.

m. Network software must allow WES users the ability to write application software suitable for a networking environment.

Phased implementation plan

103. The plan to build a comprehensive high-speed data communications system is based on a conservative approach to the changing technology and solving some immediate problems using proven technology. The following phased approach suggests some major tasks for the near term that will build a foundation for the future.

a. Evaluate and select a low-speed data switch soon. This will provide terminal access to departmental and central machines including the supercomputer front end and the CDB.

b. Design and install a fiber-optic backbone. This can currently be used for access to the central machines and the supercomputer front end using the backbone as a single token ring, and as the medium to connect bridges.

c. Advise and assist departments in installing PC-based LAN's. ITL should develop expertise and experience by installing and operating several PC LAN's. This will allow ITL to advise on standards and technology issues and on the means to connect to the backbone. This is the most important task since the pitfalls of the new technology are as yet unknown and a bad decision in installing an incompatible LAN will be costly.

d. Connect token-ring-based LAN's, and Ethernet based LAN's, using the fiber-optic backbone to form a network by means of copper wire technology. This is very inexpensive and is proven technology; it would provide access to the CDB in the early stages and would allow ITL to obtain experience in station-wide network management.

e. Advise and assist departments in installing minicomputer LAN's such as DECNET and Ethernet. ITL can develop the expertise on DECNET and Ethernet using the front-end machine for the supercomputer and the microVAX computers. ITL should experiment with terminal servers and different wiring schemes and with software that will allow DECNET TCP/IP to communicate effectively.

f. Investigate the evolving cabling technology in order to advise the departments on wiring buildings to accommodate LAN's. The technology of an unshielded twisted pair is being used for 10-Mbps Ethernet and is predicted to be used for 16-Mbps token ring LAN's. Thin wire coaxial cable is used extensively with workstations and DECNET. Fiber-optic cable is even being used for Ethernet. The field of cabling is evolving rapidly and promises to bring low cost and ease of installation in the near future.

g. Install bridges to connect departmental LAN's to the supercomputer front-end computer. This is an inexpensive solution for the present and will provide experience with management of the network.

h. Study the evolving gateway technology and standards. It would be premature to install gateways initially and the costs are too high. The future promises increased competition and reduced prices due to evolving standards and chip technology. The management software is also of major concern and needs to be experimented with to gain a real understanding of the issues involved.

i. Install gateways as the technology matures and the need for high-speed access requires it. These will be located at major buildings and will connect the stable departmental LAN's to the backbone. ITL should experiment with gateways in the near future to begin the process of developing an experienced staff.

j. Develop knowledge about DDN. This technology is in a state of flux and the Department of Defense may restrict access to DDN in the future. A short-term method of access to the outside is required and needs to be developed.

Staff requirements

104. Because the token ring can accommodate Ethernet, XNS, DECNET, and special protocols, each laboratory can independently make decisions on computing and communications. The laboratories will establish LAN's based on DEC, IBM mainframes using SNA or 4-Mbit token rings, and PC's. These networks will increase considerably over time and can be interconnected through the high-speed gateways using TCP/IP. OA is unknown at this time but the high-speed design allows for OA to be based on IBM mainframes, PC's, or DEC computers. The administration of a WES Network (WESNET) requires that present staff be freed to meet the rising work on communications. Experience with other large-scale network designers demonstrates a need for management in the following areas.

105. Personnel will be required to manage the high-speed network after installation. An estimated five positions will need to be filled as listed below.

a. One troubleshooter.

b. One person to manage host tables and mail programs.

c. One person to serve as a focal point in answering questions.

d. A manager of operations for the entire network.

e. One person to write documentation.

In addition, a full-time, vendor-provided technician may be required at WES depending on the growth of the vendor network over time.

106. Because WESNET will be based on a vendor-independent, high-speed multitoken ring implementation, the backbone network does not conform to any of the Institute of Electrical & Electronic Engineers (IEEE) 802 or ECMA recommendations for standards. In general, these recommendations are for speeds of 4, 16, and 64 Mbps.

107. With this high-speed network as the backbone and IEEE 802.5 LAN's used in the buildings, the backbone bridge will not be able to properly route the error frames, so problem determination will have to be done on a building basis. Even if Ethernet is chosen as a single implementation, the management techniques require very highly trained personnel and a fair amount of time. The present plan intends to link the various LAN's together with TCP/IP; however, TCP/IP is restrictive in that it does not have a full function set for supporting PC's and intelligent workstations. TCP/IP was designed by DARPA primarily for CPU-to-CPU file transfer and message exchange. While the use of TCP/IP limits the functioning of the network, third party TCP/IP software exists that would allow a variety of mainframe and small computers to be interlinked.

APPENDIX A: SITE VISIT REPORTS

1. The following universities were used as potential models for the US Army Engineer Waterways Experiment Station network. Visits were made to each of the universities to determine their requirements and solutions for voice and data communication needs. The results of field trips are given in this section.

University of Colorado

2. The University of Colorado network is primarily an Ethernet interconnected by AT&T's ISN. ISN also provides terminal acccess from any campus phone and supports 1,100 endpoints (700 terminals and 400 host ports) using three-pair wire. All buildings on the campus were rewired for ISN. A Proteon 80 backbone is planned for future installation and will replace the DELNI used to bridge Ethernets.

3. A System 85 premise-based voice system (PBX) is used for the voice system. Although this is a digital PBX, very little use is made of it to support data. The telecommunications department feels that the AT&T support for the System 85 PBX was poor. Phone lines total 10,000 with 300 used for digital communications through the System 85 PBX.

4. Cost of the combined contract for voice and data (to date) is $11,000,000. This includes an ISN port with every phone jack and 8 strands of fiber to 65 buildings. The ISN consists of three packet controllers and 20 concentrators. The ISN will communicate with a System Network Architect network but has problems in that it does not disconnect on periods of inactivity. Digital microwave is used as a backup for the backbone connection.

5. The university maintains a staff of 9 people for the data network and a telecommunications staff of 35. Their recommendation is to hire a cable designer and installation consultant, to expect conflicts with AT&T management, and to maintain a large staff to service the voice and data system.

Carnegie Mellon University

6. Carnegie Mellon University (CMU) is a research university of about 4,100 undergraduate and 1,500 graduate students, with a faculty of 500. Its

computer center has an assortment of Digital Equipment Corporation computers and an IBM 3083. About 1,500 personal computers (PC's), including IBM and Apple, are in use around the campus. There are also about 100 Perq Systems workstations networked together running the locally developed Accent software.

7. The computer center has built up a large ISN asynchronous terminal network that connects almost 1,500 terminals or microcomputers to about 800 ports. This network grew to about 1,000 connections using Timeplex statistical multiplexers but was almost totally converted to fiber optics in 1983. Within the center, the multiplexer lines feed into two interconnected Micom Micro-600 port selectors that provide switching and contention services to all computer center equipment and some department gear.

8. CMU Digital Equipment Corporation Network (DECNET) provides alternate routes between CMU nodes. The extensive use of Ethernet led to an interconnection problem that was solved by using Transport Control Program/Internet Protocol (TCP/IP) Ethernets on separate cables. These Ethernets now serve several hundred nodes.

9. Many other departments were connected by TCP/IP to extensions of the Computer Science Department's Ethernet or by DECNET to the Computation Center, based mainly on whether their VAX's ran VMS or Unix.

10. Major goals of the University are to interconnect the two principal types of networks on campus (the DECNET and the TCP/IP network), to accomplish high-speed networking of the microcomputers and the hosts, and to install file servers for microcomputer clusters.

11. The microcomputer area consists of a Kermit asynchronous terminal emulator program for the IBM PC, the MIT TCP/IP code for IBM PC's, Proteon's Pronet, 3Com's Ethernet, and the Novell Netware file server software. Networking technology was supported by Proteon's Pronet, TCP/IP for VAX/VMS, a prototype IBM cabling system, and CMU's stand-alone IP router. LATTICE-NET is used to route Ethernet over IBM cabling.

12. The Carnegie-Mellon internet is shown in Figure A1.

University of Pittsburgh

13. The University of Pittsburgh consists of 33,000 students with 7,600 staff/faculty. Networking for 57 buildings is accomplished with 358 miles of fiber.

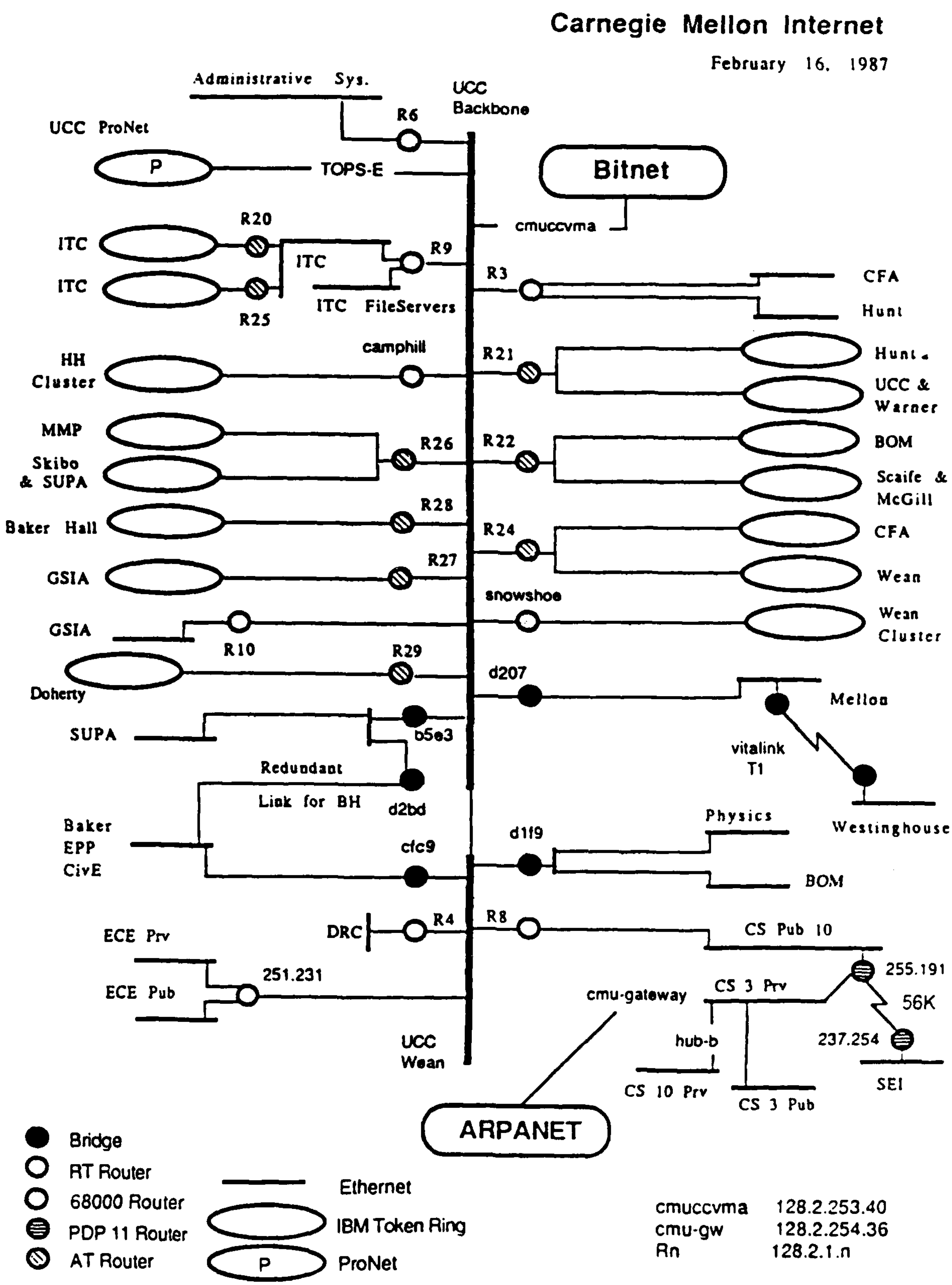


Figure A1. Carnegie Mellon internet

14. The voice system is an AT&T System 85 PBX with 15 modules presently supporting 15,000 stations. The System 85 was chosen over Centrex because it was felt that an increase in costs could be expected with Centrex in future years and because of the 3- to 15-day service turn-around through the local Bell Operating Company. The System 85 is used for voice only, even though it has combined voice and data capabilities. A separate data system consists of eight ISN nodes on campus and three remote nodes off campus connected by T1 lines at an average cost of $300/line for data. The ISN provides connections to 3,200 end-point locations.

15. Staff size includes 15 technical personnel and 4 operators for the voice system and 7 technical personnel and 3 network engineers for the data network.

University of Iowa

16. The University of Iowa voice/data system consists of an NEC2400 PBX voice system and a SYTEK 2000 data network. The NEC2400 supports 12,000 end points on campus and includes a separate hospital switch with an additional 8,000 end points.

17. The SYTEK backbone consists of three coaxial cables, one of which is used for video and another for data. There are 1,000 data end points of the SYTEK network with 350 computer ports located at the computer center. Cost was $300-$500/port to connect to the SYTEK network.

18. A Pacific Northwest local area network (LAN) is used to connect 75 PC's with 5 file servers, each with 150-Mbyte hard drives. Port connection is via one hundred and twenty asynchronous ports, twenty-four 3270 ports, and a T1 gateway between LAN's.

19. Each outlet at the University of Iowa is wired with a two-pair twisted wire for voice, and a three-pair twisted wire for data that feeds into the SYTEK network. Over 1,200 ports are connected by RS232 into the SYTEK network with a contention ratio of 2 to 1. Network computers include Prime, IBM, VAX, and Encore.

20. The SYTEK is a 300-Mhz broadband network. Each 6-Mhz bandwidth can accommodate 20 subcarriers and each subcarrier can handle 100 conversations, for 2,000 connections per 6-Mhz channel.

University of Pennsylvania

21. The University of Pennsylvania has 17,000 students. Centrex provides the voice communications, and ISN, with 15 remote nodes, is used for data. The ISN serves 2,000 end points. An AT&T-installed backbone connects the 15 ISN nodes with 54 miles of fiber. A staff of 25 maintains and services the data communications network.

22. Ethernet LAN's are used in departments and are connected to the ISN. TCP/IP is a standard for interconnectivity of the Ethernet allowing document retrieval from ALL-IN-ONE and DISSOS. Twelve Ethernet bridges are used in the network.

23. Computers include PC's, IBM 4381 mainframes and DEC VAX computers. DEC computers talk both DECNET and TCP/IP.

24. The network can be summarized as supporting asynchronous communications, Ethernet to Ethernet, 3270 to asynchronous, TCP/IP, PC networks based on TCP/IP, office automation, Telenet, and BITNET networks.

25. The wiring plan uses a 4-pair unshielded, a 4-pair shielded, and a coaxial cable for thin Ethernet connection. An average of 50 end points a month are being added to the network with a total cost to date of $8,000,000 for the network.

26. C.O.LAN is being installed on a trial basis at the University and is currently available only in the immediate vicinity of the main campus. C.O.LAN will be used mainly for asynchronous-type connections.

27. The university charges a monthly fee of $20.00 for an ISN port or a Gandalf port connection.

University of Illinois

28. The University of Illinois supports a large data network based on the Proteon Pronet-80 backbone. A total of 61 buildings are wired with 12 strands of fiber to each building. Five of the buildings serve as major distribution centers. The Proteon backbone ties together over 120 LAN's on the campus consisting of a Cyber 175, IBM mainframes, DEC VAX computers, Sequent and Pyramid super-minicomputers, and a Cray X-MP supercomputer. The separate LAN's range from low-speed, low-cost, twisted-pair telephone line networks to the 50-Mbps Hyperchannel. IBM's PC network, a 2-Mbps broadband

system, runs off of the SYTEK localnet backbone to serve many departments and classrooms on campus. Academic and administrative departments use Hyperchannel, Proteon's Pronet-10, and Ethernet systems to network users on PC's and super-minicomputers.

29. Flexibility in terms of multivendor connectivity and open protocol support was a prime consideration in the design of the network. Open protocol support would maximize communication possibilities. TCP/IP became the University's choice protocol because it is well-supported and provides a good migration path to the International Standards Organization's Open System Interconnection protocols.

30. The University considered extending the Ethernet backbone operating at 10 Mbps over coaxial cable. However, because of traffic loads, it was felt the 10-Mbps rate was insufficient.

31. Another approach considered was to extend the existing 50-Mbps Hyperchannel. However, in this case, the University was concerned about the lack of an open protocol and the cost of the equipment.

32. In 1985, Proteon, Inc. introduced its 80-Mbps Pronet-80 token ring network. The Proteon-80 backbone met the needs of the University in providing a collision-free network with an open protocol while supporting a variety of vendor equipment.

33. Fiber is an ideal transmission media for the backbone network due to its immunity to electrical noise and its high bandwidth. The engineers at the University have designed a very complex network that is layered around the Pronet-80 fiber backbone. The fiber is carried in an underground conduit system consisting of 4-in. plastic pipes, with a minimum of four pipes to each building. Thirty-four Proteon P4200 gateways are used in the network with 110 IP nets, 600 computers, and 5,000 users.

34. The University maintains a staff of seven for troubleshooting, installing table management, network mail, and for advising other departments on connecting to the network. The network topology for the University is given in Figure A2.

University of California, Berkeley

35. The University of Calfornia, Berkeley "Campus Area Network" infrastructure is designed for up to 20,000 nodes (workstations, servers, and

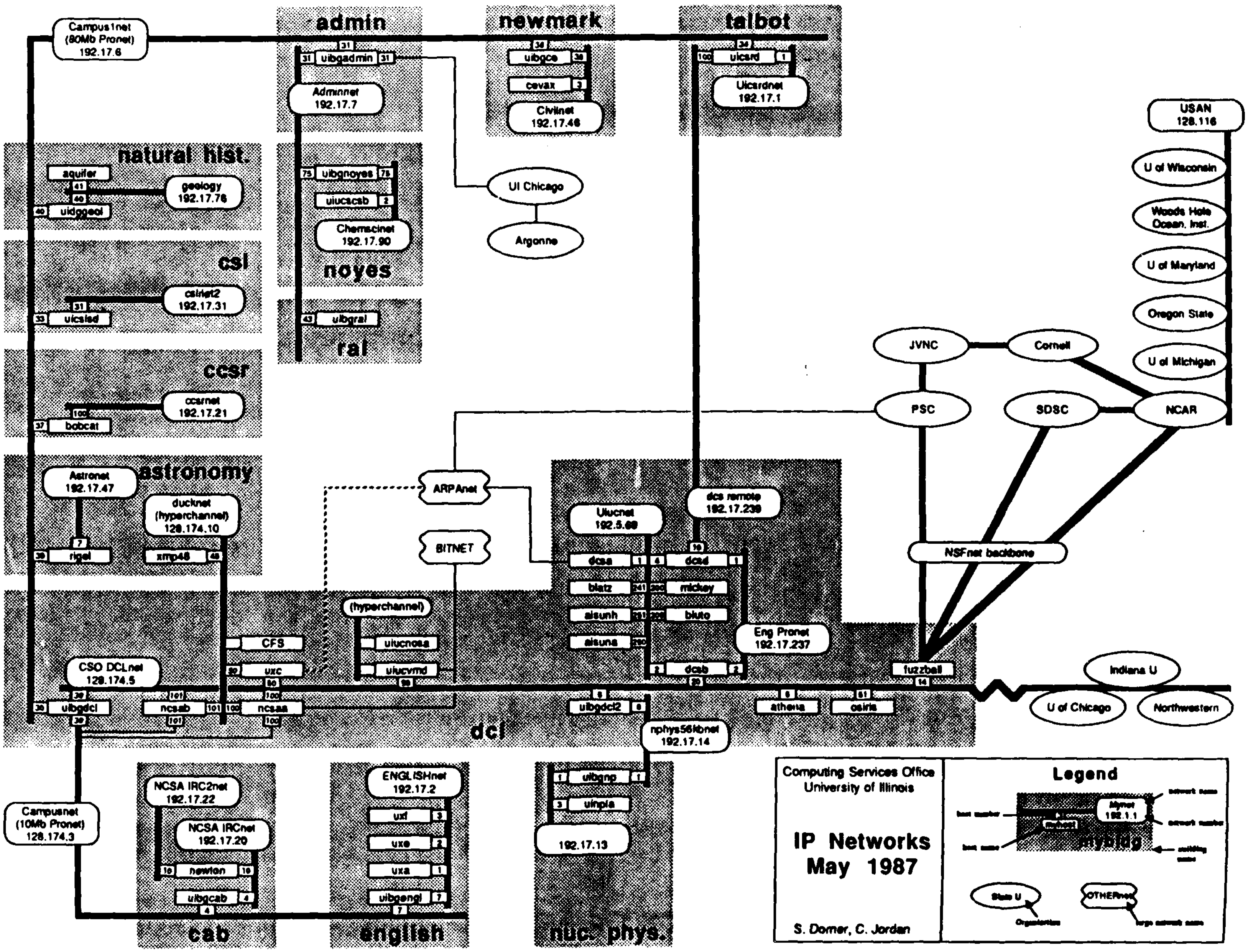


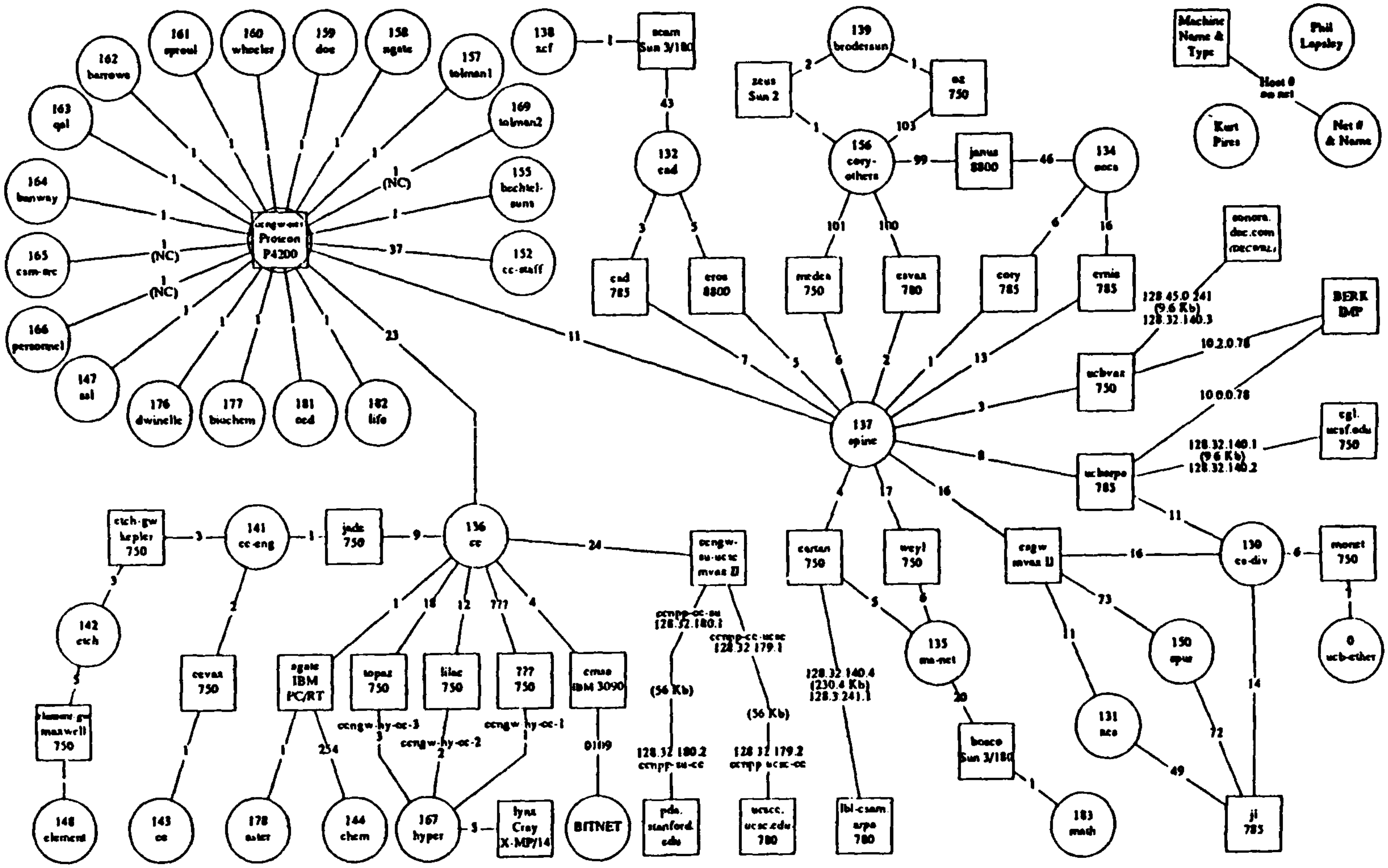
Figure A2. Network topology for the University of Illinois resources), and is a three-level hierarchial network using internetwork routers between local Ethernet subnets and high-speed backbone subnets. The network provides internetwork gateways to regional, national, and international networks (BARRNET, ARPANET, BITNET, NSFNET, etc).

36. The Pronet-80 is used as the backbone network and supports communication to the various department LAN's. Installed in December 1986, the Pronet-80 consists of 20 subnet gateways at a cost of $10,000 to $12,000 per gateway. There are an additional 33 Proteon gateways, and support for microwave linkup is included.

37. The University maintains a staff of four people to assign internet addresses to do troubleshooting. With a total of 32,000 students, 3,000 faculty, and 9,000 staff, the goal of the university is to connect 20,000 engineering workstations on the campus network.

38. Networking for the University of Calfornia, Berkeley, is shown in Figure A3.

The Berkeley Network – 15 March 1987



Circles represent 10 Mb/sec ethernets, except for network 167, which is a hyperchannel; network names and subnet numbers are shown within the circle. Squares represent gateway machines; machine names and types are shown within the square. The line between a circle and a square indicates the address of the gateway on the given subnet. Berkeley's class B address is 128.32, so, for example, "[illegible]" is 128.32.156.100, as well as 128.32.137.2. Note that hosts other than gateway machines are not shown.

Janus does not forward packets between the 156 and 134 nets to avoid routing loops.

Subnet 0, "ucb-ether", was a 3 Mb ethernet which is no longer in use.

Network map courtesy of the Experimental Computing Facility. University of California, Berkeley

The "[illegible]" Proteon P4200 "circle-square" is actually a group of Proteon gateways connected by Pronet-80 fiber and 56 Kb point-to-point links. A separate map is available for this topology.

UUCP links to other sites are not shown, and exist on "ucbvax", "cad", "ucbarpa", and "[illegible]". The few remaining [illegible] serial links are also not shown.

Figure A3. Networking for the University of California, Berkeley

APPENDIX B: VAX COMPUTERS AT US ARMY ENGINEER WATERWAYS EXPERIMENT STATION (WES)

1. The following table is a summary of the VAX computers and associated facilities at WES.

Table B1

Present Environment

Bldg	Lab	Mini Computer	Network	PC's	Modems	Other
6000	SL	1 HP 9000 with 14 RS232 11 HP 200/300 Computers		23	12	1 terminal
6000	EL	2 VAX 750	DECNET			
3200	HL	2 VAX 750 1 uVAX II 1 Silicon Graphics IRIS 10 NBI WS		100	85	2 Masscomp (series 500)
1000	ITL	1 Honeywell Infotron 4400 1 IBM 4331 1 Harris 500	RS232	100	100	
5014	SL	1 VAX 750 1 uVAX II 1 uVAX I		14	2	30 terminals
5008	SL	1 VAX 750	secure VAX			
3396	GL	16 NBI		175	100	24 PC IBM LAN
3288	GL	1 VAX 785 2 uVAX II 1 PDP 11/44 1 PDP 11/24 1 VAX 730 1 VAX 750	DECNET	25	15	1 Masscomp
3286	GL	3 NBI		20	20	
3284	CERC	1 VAX 750 1 uVAX II				
3279	ISD	1 uVAX I				
1006	EL	2 VAX 750		100	100	
2055	ITL	IBM 9370				

2. The following is an estimate of future VAX equipment which will be needed over the next 3 years.

45 VAX computers including 750's, 785's, uVAX II's, and uVAX I's

1 VAX 8800

1 Supercomputer

1,800 analog phone lines

1,000 data lines (simultaneous data over voice over a single twisted pair)

1,000 voice/data multiplexers for the 1,000 data lines

200 300/1,200/2,400-baud modems

20 9,600-baud leased line modems

20 4,800-baud leased line modems

20 9,600-baud dial-up modems

50 PC local area networks with an average of 25 PC's per network

3 IBM 9370

1 IBM 4331

1 Honeywell

10 Masscomp Series 500

1 HP 9000

15 HP 200/300 computers

1 Silicon Graphics IRIS

1 Harris 500

100 PC workstations with NBI boards